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ANATOMY OF *FUTALOGNKOSAURUS DUKEI* CALVO, PORFIRI, GONZÁLEZ RIGA & KELLNER, 2007 (DINOSAURIA, TITANOSAURIDAE) FROM THE NEUQUÉN GROUP (LATE CRETACEOUS), PATAGONIA, ARGENTINA [1]

(With 20 figures)

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ABSTRACT: Titanosaurs are among the largest dinosaurs known to date. Here we describe the anatomy of *Futalognkosaurus dukei*, the most complete giant sauropod ever found. It comes from outcrops of the Portezuelo Formation at the Barreales lake, some 90 km northwest of Neuquén city (Patagonia). The specimen consists of a complete neck, dorsal vertebrae with ribs, pelvis, and one caudal vertebra. *Futalognkosaurus dukei* is a member of the Titanosauridae and belongs to the Lognkosauria, a clade that includes *Mendozasaurus neguyelap* and probably also the giant *Puertasaurus reuili*.

Key words: Dinosauria. Titanosauridae. Lognkosauria. Neuquén Basin. Patagonia. Argentina.

RESUMO: Anatomia de *Futalognkosaurus dukei* Calvo, Porfiri, González Riga & Kellner, 2007 (Dinosauria, Titanosauridae) do Grupo Neuquén (Cretaceous Superior), Patagônia, Argentina

Titanossauros são alguns dos maiores dinossauros conhecidos. Neste trabalho descrevemos a anatomia de *Futalognkosaurus dukei*, o mais completo dos saurópodes de grande porte encontrado até a presente data. O material é procedente de afloramentos da Formação Portezuelo situados no lago Barreales, situado aproximadamente a 90 km noroeste da cidade de Neuquén (Patagônia). O espécime consiste da série cervical completa, vértebras dorsais e costelas, a pélvis e uma vértebra caudal. *Futalognkosaurus dukei* é um membro de Titanosauridae e pertence ao clado Lognkosauria que inclui *Mendozasaurus neguyelap* e provavelmente também o gigantesco *Puertasaurus reuili*.

Palavras-chave: Dinosauria. Titanosauridae. Lognkosauria. Bacia de Neuquén. Patagônia. Argentina.

INTRODUCTION

During the last years, extensive field works have been carried out at the North coast of the Barreales Lake, Neuquén Province, Argentina (Fig.1). This site, named Futalognko, is located in the region known as the Proyecto Dino and has yielded a large quantity of fossils making it one of the most important dinosaur localities in South America (Calvo *et al.*, 2002a; Porfiri & Calvo, 2004, Calvo *et al.*, 2007). Among the material recovered are sauropod postcranial elements, several sauropod teeth (Calvo & Grill, 2003), indeterminate ornithopods (Porfiri & Calvo, 2002; Calvo & Porfiri, 2003), and new specimens of the theropods *Megaraptor namunhuaiquii* (Calvo *et al.*, 2002b; 2004b; Porfiri & Calvo, 2003) and *Unenlagia paynemili* (Calvo *et al.*, 2003; Calvo *et al.*, 2004a). Theropod teeth assigned to dromaeosaurids (Poblete & Calvo, 2003) and carcharodontosaurids (Veralli & Calvo, 2004) were also found. The fossil record of this site includes also fish specimens (Gallo *et al.*, 2003), crocodylomorphs (Poblete & Calvo, 2005), pterosaurs (Kellner *et al.*, 2004; 2007), angiosperms and gymnosperms (Prámparo *et al.*, 2003; Passalia *et al.*, in press). Among the most spectacular finds at the Futalognko site is a partial skeleton of the giant titanosaur sauropod *Futalognkosaurus dukei* (Calvo *et al.*, 2007) which was collected between 2000 and 2005 (Calvo,

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2000, 2006; Calvo *et al.,* 2001). The aim of this paper is to describe in detail the anatomy of this giant sauropod.

Geological Setting

The Neuquén Group, of Late Cretaceous age (Digregorio, 1972; Cazau & Uliana, 1973), includes continental deposits formed in a restricted environment. The stratigraphic sequence is composed by alternating successions of sandstones, mudstones, conglomerates, and conglomeratic sandstones (Fig.2). The Neuquén Group is divided into the following subgroups: Río Limay, Río Neuquén, and Río Colorado (Ramos, 1981). The outcrops in the area of the Dino Project correspond to the Rio Neuquén Subgroup (Sánchez *et al.*, 2003) and the sauropod described here comes from Portezuelo Formation (Late Turonian-Lower Coniacian, after Leanza & Hugo, 2001). Outcrops are 20 meters thick and are covered by deposits assigned to the Plottier Formation. Both formations differ showing a notable change in the proportion between channels filling with respect to floodplains deposits, suggesting distinct paleoenvironmental conditions. Moreover, there is a well differentiated fluvial system represented in those units that changes from an intermediate to a high sinuosity system (Sánchez *et al.*, 2005).

Only the upper part of the Portezuelo Formation is exposed at the Futalognko site, representing a fluvial system characterized by several variations between channels and floodplain deposits, channel design, and spatial distribution, with slightly fining upward sequences. Facies associations allow us to postulate that the upper part of the Portezuelo Formation on the Barreales Lake shows three kinds of deposits. There are well developed sandy channels with mixed-loaded fluvial system, a second fluvial system of low to moderate sinuosity with predominance of lenticular channels, and architectural elements (*sensu* Mial, 1996) like lateral accretion and overbank facies on the floodplain. Toward the top of the unity the subsidence rate increased slightly, resulting in the development of flooding areas with established bodies of water where the dinosaur described here and other fossils were preserved. Over this sequence, a highly sinuous meandering fluvial system was installed.

The Plottier Formation is superposed to the Portezuelo Formation, being almost horizontal and showing a gradual transition from the latter.

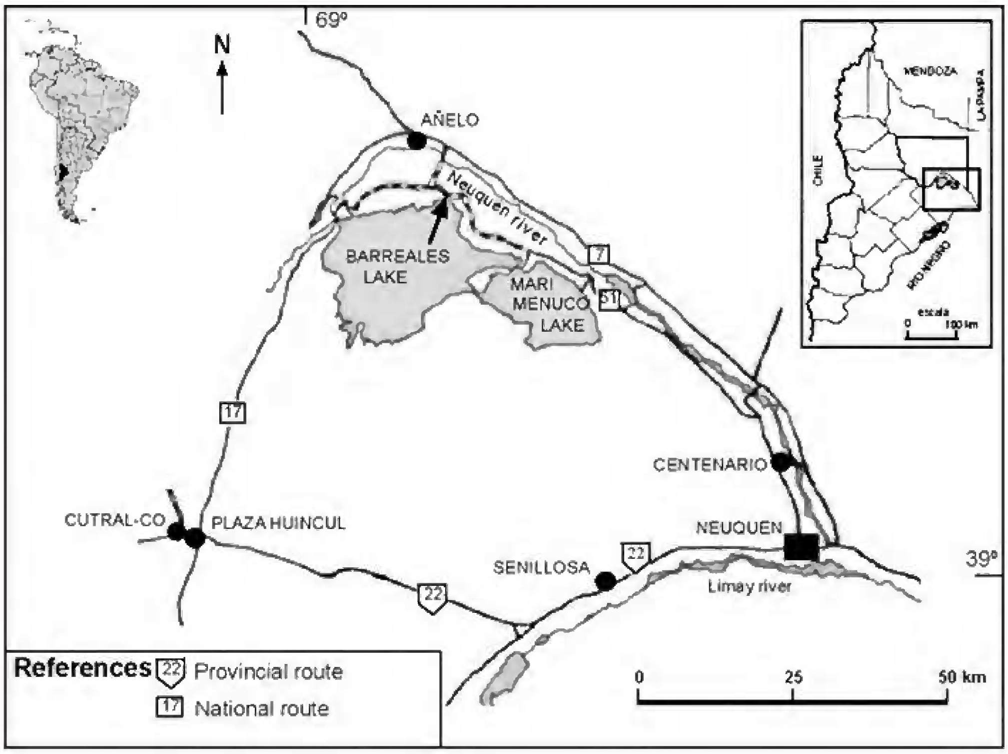


Fig.1- Map of Neuquén Province (northwest Patagonia) showing where *Futalognkosaurus dukei* was found.

A low rate between channels over floodplain deposits is found on the basal section with a high aggradational floodplain, indicating the development of an ephemeral fluvial system (SÁNCHEZ *et al.*, 2006). The restriction of the channel system may be related with the climatic conditions, probably combined with subsidence that would have temporarily controlled the system with strong aggradation of fine sediments in the floodplain, with periodic events of sheet flood and the development of shallow channels limited in their migration by the cohesiveness of the coast. Gradually, a braided fluvial system was developed, building *levees* and avulsion deposits associated with *crevasse* channels. Therefore, the Plottier Formation is characterized by a low sinuosity system and it is dominated by an intense aggradation of the floodplain (SÁNCHEZ *et al.,* 2006).

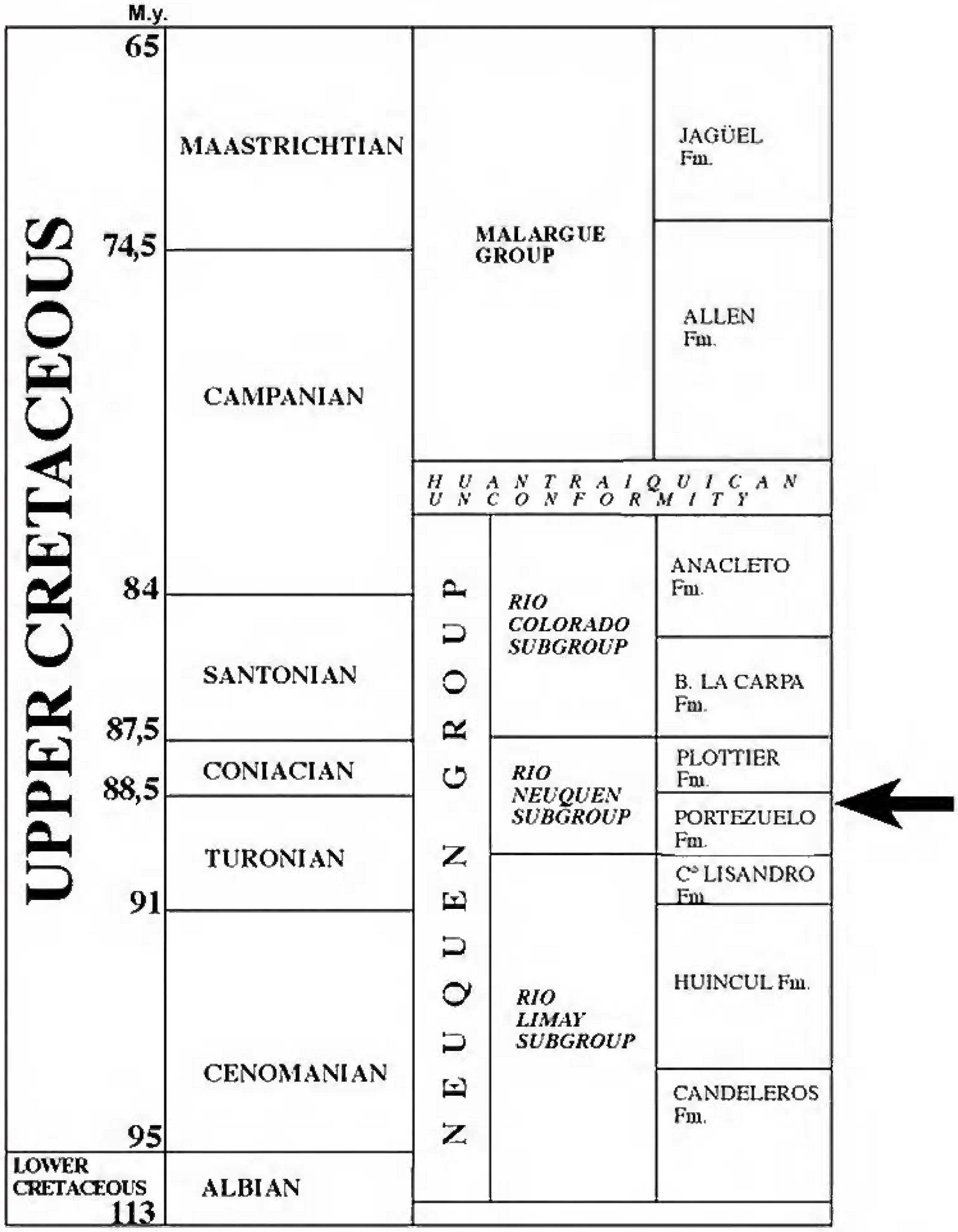


Fig.2- Stratigraphic column of the Neuquén Group (modified from LEANZA & HUGO, 2001). Arrow indicates the stratigraphic position of the Futalognko site. (M.y.) millions of years.

SYSTEMATIC PALEONTOLOGY

Saurischia Seeley, 1887
Sauropodomorpha Huene, 1932
Sauropoda Marsh, 1878
Titanosauria Bonaparte & Coria, 1993
Titanosauridae Lydekker, 1893
Lognkosauria Calvo, Porfiri, González Riga & Kellner, 2007
Futalognkosaurus dukei Calvo, Porfiri, González Riga & Kellner, 2007

Holotype – Atlas, axis and five anterior, four middle and three posterior cervical vertebrae, 10 dorsal vertebrae, several ribs, complete sacrum, both ilia, right pubis and ischium, and one anterior caudal, housed at the Museo de Geologia y Paleontologia de la Universidad Nacional del Comahue under the number MUCPv-323.

Diagnosis – Neurapophyses of the atlas laminar and quadrangular, posteriorly directed; neural spine of the axis high, triangular; posterior border of the neural spine on middle cervical elements concave; ventral depression between parapophyses on middle cervical centra; anterior dorsal vertebrae with horizontal and aliform diapophysis; pre- and postzygapophyses of anterior dorsal vertebrae horizontal; first caudal vertebra with prespinal lamina bifurcated on its base forming two small infraprespinal laminae; supraspinal cavity in first caudal vertebra bordered by the prespinal and lateral laminae; 2nd and 3rd sacral ribs fused; wide and well developed iliac peduncle on ischia (Calvo *et al.*, 2007).

DESCRIPTIONS AND COMPARISONS

Cervical Vertebrae

The atlas is one of the best preserved of any known Titanosauria (Fig.3). The articulation with the occipital condyle is wider than high. In lateral view, the neural arch is displaced posteriorly (Fig.4). The neurapophyses is a thin quadrangular lamina that expands upward and curves medially, with the distal end directed posteriorly. There is no contact between both neurapophyses at the midline.

Fig.3- *Futalognkosaurus dukei*; atlas in anterior view. Scale bar =100mm. (NA) neurapophyses.

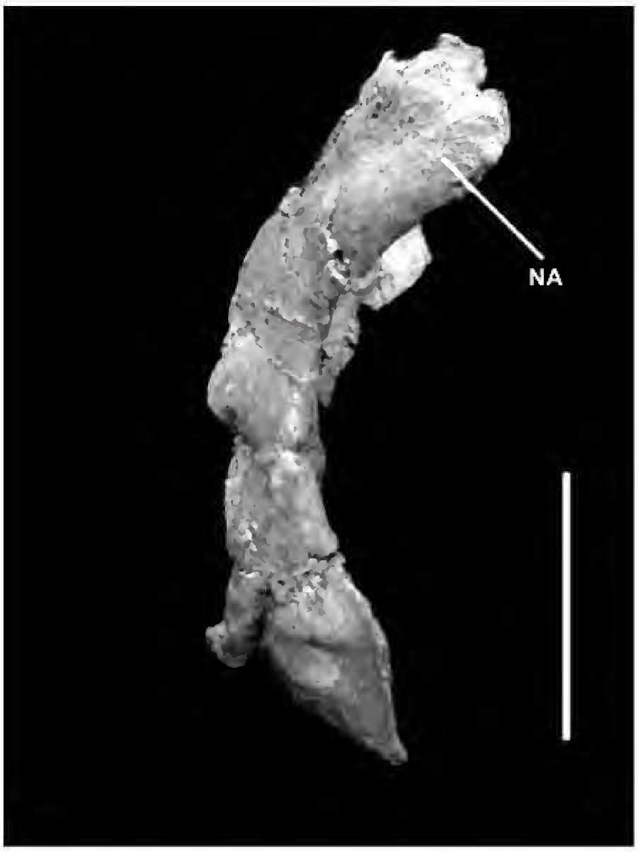
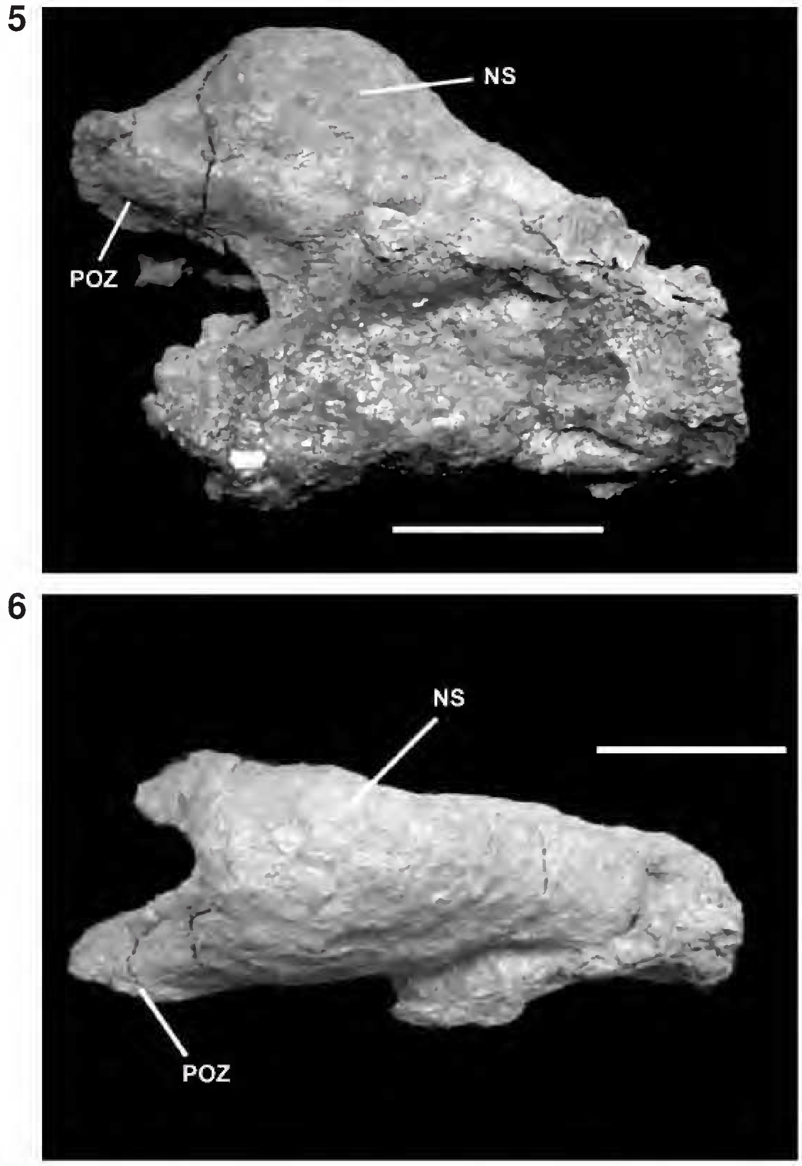


Fig.4- *Futalognkosaurus dukei*; atlas in lateral view. Scale bar =100mm. (NA) neurapophyses.

The axis has a short and high neural arch (Figs.5-6). It occupies 2/3 of the total height of this element. The odontoid process has not been preserved. The neural spine is high, robust, of triangular shape. The centrum is elongated without pleurocoels, differing from *Saltasaurus* (POWELL, 1986) and *Alamosaurus* (LEHMAN & COULSON, 2002). Prezygapophyses were not preserved and postzygapophyses have a horizontal articulation.

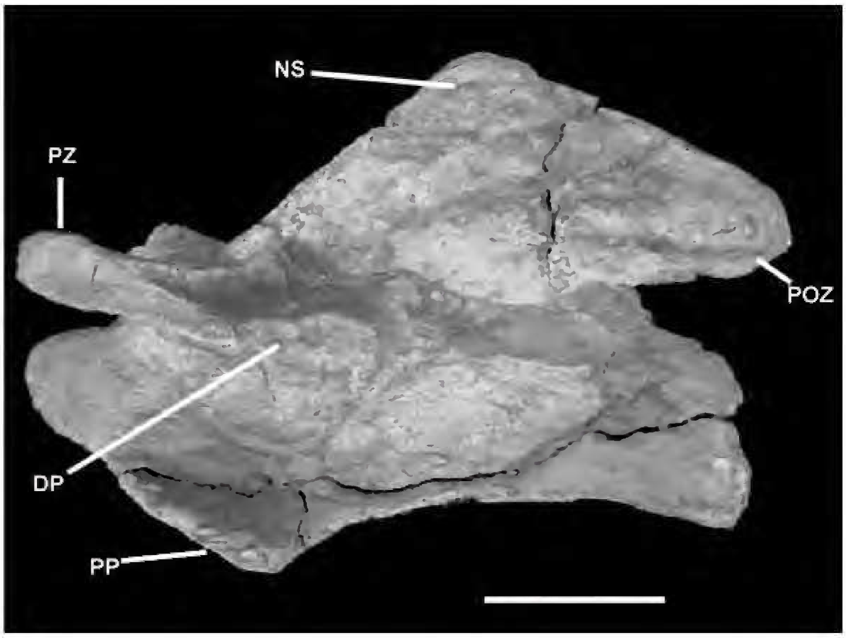
All cervical vertebrae are opisthocoelous with the neural spines not bifurcated. Anterior cervical elements are longer than high (Fig.7). The triangular neural spine is robust and directed posteriorly. The third cervical vertebra has robust spinoprezygapophyseal and spinopostzygapophyseal laminae and a smooth channel is developed between them (Fig.8). On the fourth cervical, a deep channel between both spinoprezygapophyseal laminae is present, a feature observed in the following elements of the neck. This channel does not reach the top of the neural spine as observed in titanosaurid cervical sequence from Brazil known in the literature as the series A (POWELL, 1987), that latter received the number MCT 1487-R (CAMPOS & KELLNER, 1999). The neural spine has a triangular shape, in lateral view, and it is compressed lateromedially but elongated anteroposteriorly as the rest of anterior cervical vertebrae.



Futalognkosaurus dukei: fig.5- axis in lateral view; fig.6- axis in dorsal view. Scale bar =100mm. (POS) postspinal lamina, (NS) neural spines.

Pleurocoels are absent in all elements of the series, a feature observed in *Malawisaurus dixeyi* and in the sole cervical element known from *Gondwanatitan faustoi*, respectively from Malawi and Brazil (Jacobs *et al.*, 1993; Kellner & Azevedo, 1999). Parapophyses are laminar and restricted to the anterior portion of the centrum. The posterior centrodiapophyseal lamina is directed anterodorsally as in MCT 1487-R (Powell, 1987) and it is different to that present in *Saltasaurus loricatus* (Bonaparte & Powell, 1980). Anterior cervical vertebrae of Titanosauria are scarce in the fossil record, limiting further comparisons.

7



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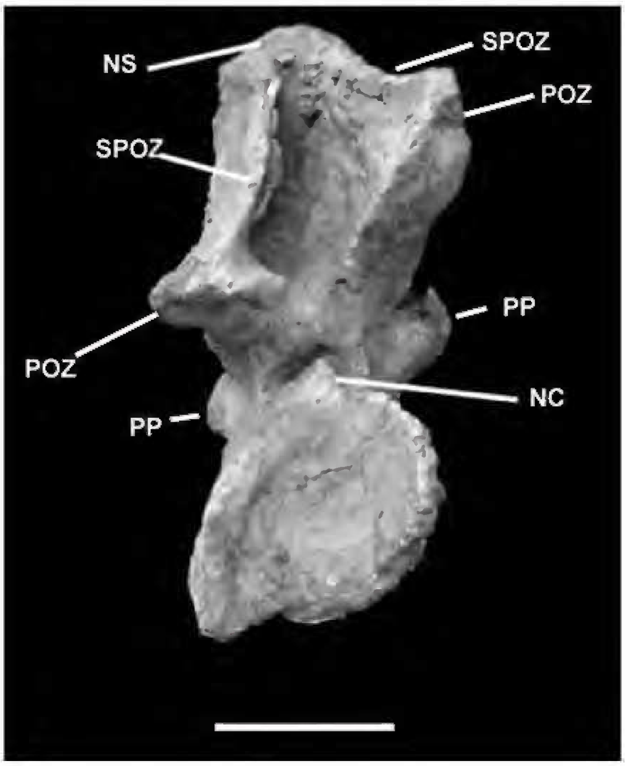

Futalognkosaurus dukei: fig.7- anterior cervical in lateral view; fig.8- anterior cervical in posterior view. Scale bar =100mm. (DP) diapophysis, (NC) neural canal, (NS) neural spines, (POZ) postzygapophysis, (PP) parapophysis, (PZ) prezygapophysis, (SPOZ) spinopostzygapophyseal lamina.

Middle cervical vertebrae are higher than long (Fig.9). The centrum lacks pleurocoels as in MCT 1487-R from Brazil, but differing from the condition reported in *Malawisaurus* and the shallow lateral pleurocoels reported by CURRY ROGERS & FORSTER (2001) in *Rapetosaurus krausei*. The prezygapophysis in *Futalognkosaurus* reaches the anterior border of the centrum, different from the condition present in MCT 1487-R and in the Saltasaurinae. The neural spine is very high and sail-shaped as in *Malawisaurus* and *Rapetosaurus*. *Futalognkosaurs* shares with *Rapetosaurus* higher neural arches in anterior and middle cervical vertebrae, three times higher than the centra. They extend over the complete length of the centra and are directed backwards. In lateral view, the spinoprezygapophyseal border is straight and the spinopostzygapophyseal margin is concave, a feature not observed in other members of the Titanosauria (Fig.9). The only taxa with similar sail-shaped neural spine is *Rapetosaurus* but it has the spinopostzygapophyseal border straight proximally and slightly concave distally. Moreover, in *Rapetosaurus* postzygapophyses are placed at middle height of the neural arch, as those present in *Rinconsaurus caudamirus* (CALVO & GONZÁLEZ RIGA, 2003). In anterior view, the spinoprezygapophyseal laminae are fused on the distal end forming a deep suboval depression. This feature resembles, in some way, that present in middle cervicals of the titanosaurid MCT 1487-R from Brazil (POWELL, 1987). However, in the latter, neural spines are very low with a rugose and wide distal end. Middle cervical vertebrae have a deep depression formed between the base of the neural spine and the diapopostzygapophyseal lamina (Fig.10). In ventral view, a deep depression is present on the proximal end of the centrum between the parapophyses. This depression is considered an autopomorphy of *Futalognkosaurus dukei*.

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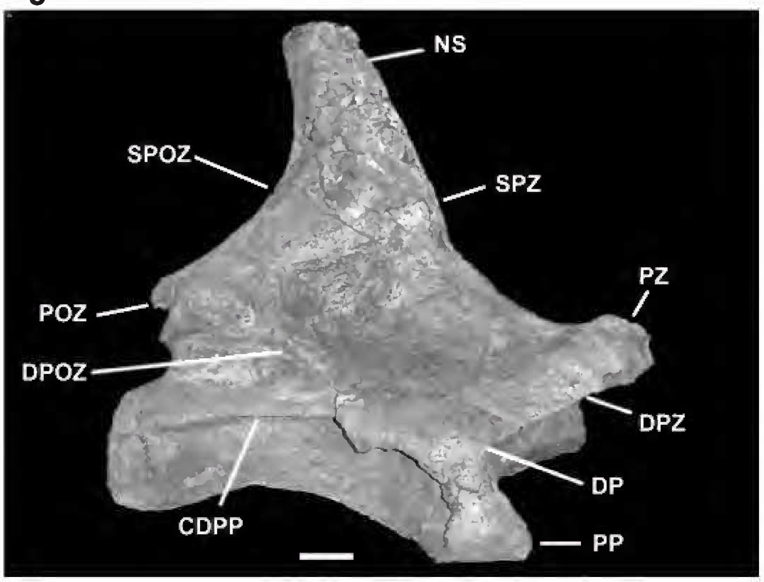

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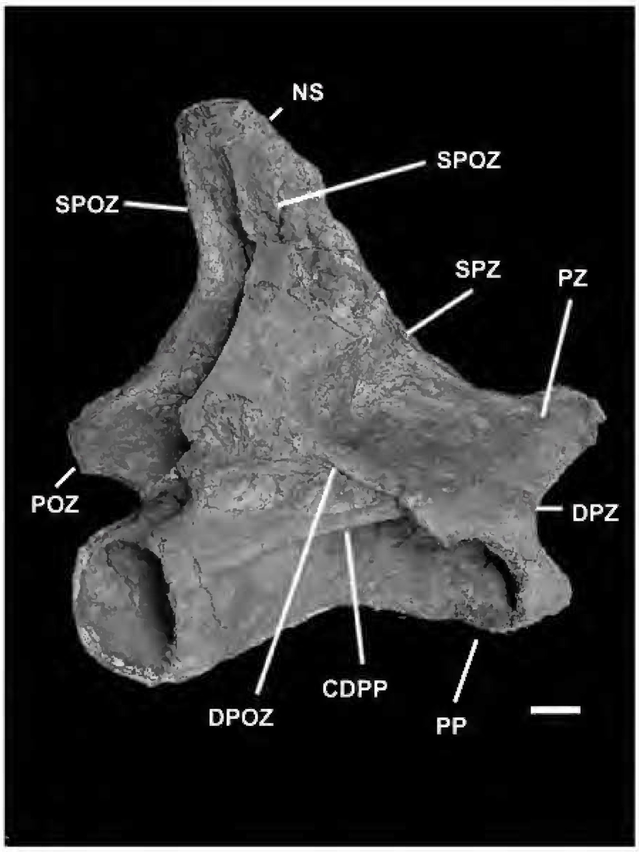
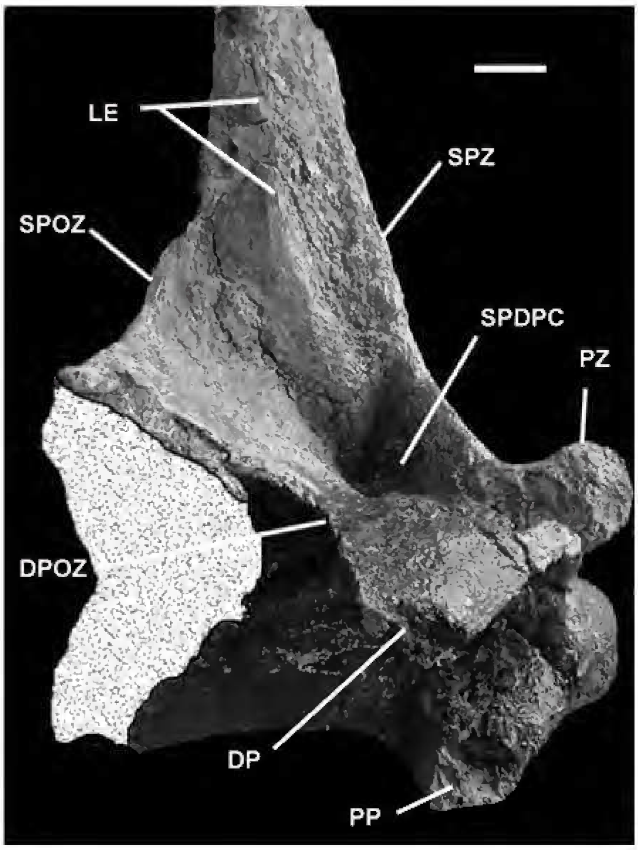


Futalognkosaurus dukei: fig 9- middle cervical in lateral view; fig.10- middle cervical in posterolateral view. Scale bar =100mm. (CDPP) centrodiapophyseal posterior lamina, (DP) diapophysis, (DPOZ) diapopostzygapophyseal lamina, (DPZ) diapoprezygapophyseal lamina, (NS) neural spines, (POZ) postzygapophysis, (PP) parapophysis, (PZ) prezygapophysis, (SPOZ) spinopostzygapophyseal lamina, (SPZ) spinoprezygapophyseal lamina..

Posterior cervicals are opisthocoelous with very elongated centra (Fig.11). Neural arches are high, being three or more times higher than the centrum, character only shared with *Mendozasaurus neguyelap* (González Riga, 2003). Neural spines are compressed proximodistally and expanded laterally as in *Puertasaurus reuili* (Novas *et al.*, 2005) and in *Mendozasaurus,* but to a lesser degree (Figs.11-12). This shape is completely different in all other titanosaurids such as *Saltasaurus*, MCT 1487-R from Brazil, and *Isisaurus colberti* (Jain & Bandyopadhyay, 1997). The neural spine is inclined slightly posteriorly, different from the condition reported in *Isisaurus colberti, Puertasaurus reuili*, and *Mendozasaurus neguyelap* that are perpendicular to the body axis. It displays an intraprezygapophyseal lamina and deep supradiapophyseal cavities as those present in *Isisaurus* and *Mendozasaurus.* In anterior view, no prespinal lamina is present (Fig.12). In *Isisaurus*, a true prespinal lamina is developed while in *Mendozasaurus* the prespinal lamina is restricted to the base of the neural arch (González Riga, 2005). Both spinoprezygapophyseal laminae in *Futalognkosaurus* are robust and reach almost the top of the neural spine (Fig.12). They are placed almost parallel to each other, leaving a slit-shaped depression between them. In *Mendozasaurus* and *Puertasaurus*, the spinoprezygapophyseal laminae are well separated and only reach the middle part of the neural spine. Other Titanosauridae such as Saltasaurinae (Powell, 1986) and Rinconsaurini (Calvo *et al.*, this volume), also show this feature, but the cavity is shallow. The last cervical vertebra (a cervicodorsal), shows a prespinal-like lamina but it does not reach the base of the neural arch. The supradiapophyseal cavity is separated by a septum from a lower depression placed on the diapophysis (Fig.13). *Futalognkosaurus dukei* differs from the giant titanosauriform *Sauroposeidon proteles* (Wedel *et al.*, 2000) which has extremely elongated cervical centra with a low neural arch, deep pleurocoels, and a deeply excavated neural spine.

11



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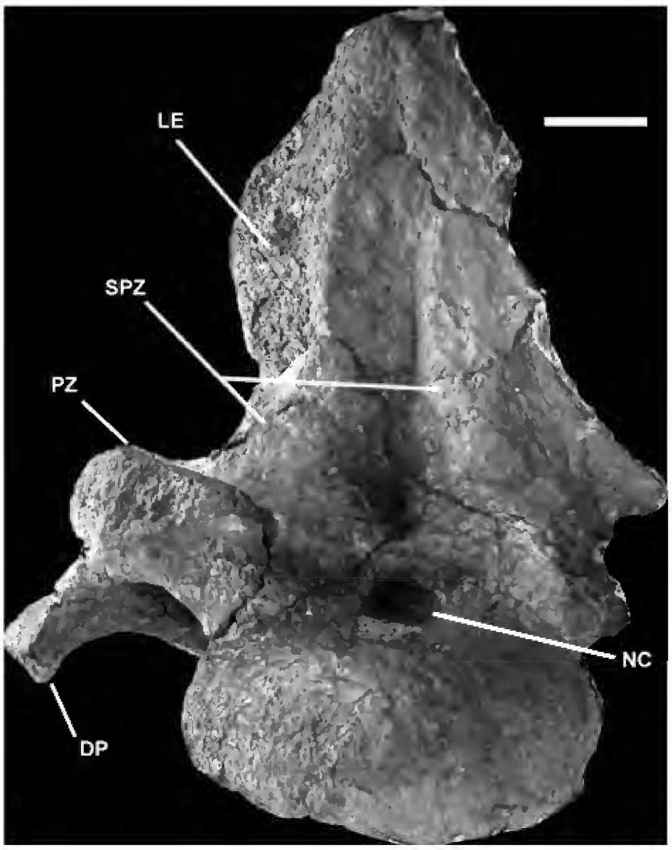

Futalognkosaurus dukei: fig.11- posterior cervical in lateral view; fig.12- posterior cervical in anterior view. Scale bar =100mm. (DP) diapophysis, (DPOZ) diapopostzygapophyseal lamina, (LE) lateral expansion, (LL) lateral laminae, (LR) longitudinal ridge, (NA) neurapophyses, (NC) neural canal, (NS) neural spines, (PC) pubis contact, (PF) pubic foramen, (POS) postspinal lamina, (POZ) postzygapophysis, (PP) parapophysis, (PS) prespinal lamina, (PZ) prezygapophysis, (SBD) spinobasaldiapophyseal lamina, (SC) supraspinal cavity, (SDP) spinodiapophyseal lamina, (SPDPC) supradiapophyseal cavity, (SPOZ) spinopostzygapophyseal lamina, (SPZ) spinoprezygapophyseal lamina, (SS) supraspinal lamina, (TP) transverse process

Dorsal Vertebrae

The ten articulated dorsal vertebrae are partially prepared, all being opisthocoelous (Fig.14). The most anterior dorsal has an elongated centrum and the second is 2/3 the length of the first. The centrum length gradually reduces in the more posterior elements of the sequence, with the first one being 43cm long and the last one 28cm (without considering the anterior ball). This pattern contrasts strongly with the cervical sequence of this species, where the length increases until the middle elements and then decreases slightly posteriorly. All dorsal vertebrae have eye-shaped pleurocoels. They lack hyposphene-hypantrum complex, differing from the condition observed in *Argentinosaurus huinculensis* (Bonaparte & Coria, 1993). All neural spines are undivided (Fig.14). Diapophyses are laminar, planar, and directed laterally, different from those of *Puertasaurus reuili* (Novas *et al.*, 2005) where they are dorsoventrally deep. The neural arch is transversely width being approximately 100cm. Neural arches on the first and second dorsal vertebrae are similar to the last cervical, being slightly directed posteriorly and different to that of *Argentinosaurus* and *Puertasaurus*, that is vertically oriented. The neural spine is united with the proximal end of the diapophysis by a structure (here named spinobasaldiapophyseal lamina), and the spinopostzygapophyseal lamina (Fig.13). These laminae are directed more laterally than in the last cervical. The prespinal lamina is present along the neural spine and reaches the base of the neural arch, different from the condition observed in *Argentinosaurus*, which has a prespinal bump. A postspinal lamina is also present. The supradiapophyseal cavity is small, slit-like and placed on the neural spine (Fig.13). Starting at the third dorsal vertebra, the neural arches and neural spines are strongly inclined posteriorly (Figs. 13-14).

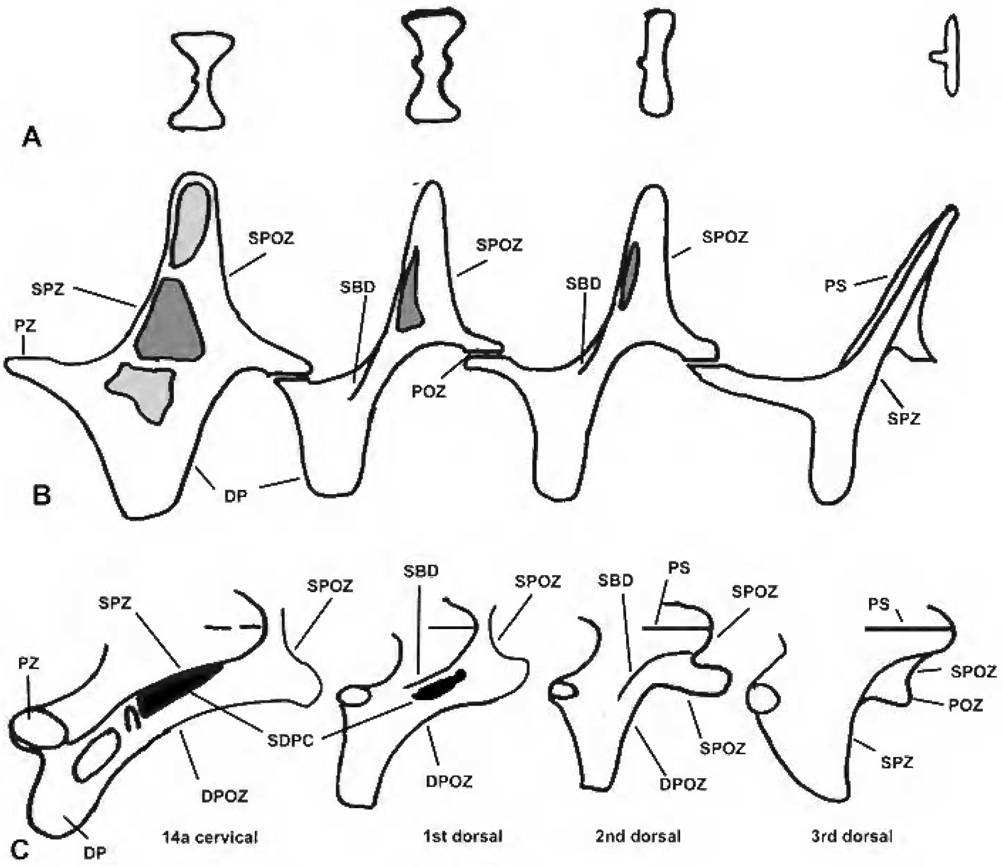

Fig.13- *Futalognkosaurus dukei*; sketch of the 14th cervical and 1st to 3rd dorsals. (A): cut section of the neural spine; (B): lateral view of the neural arches; (C) upper view of the half left neural arches. (CDPP) centrodiapophyseal posterior lamina, (DP) diapophysis, (DPOZ) diapopostzygapophyseal lamina, (POZ) postzygapophysis, (PS) prespinal lamina, (PZ) prezygapophysis, (SBD) spinobasaldiapophyseal lamina, (SPOZ) spinopostzygapophyseal lamina, (SPZ) spinoprezygapophyseal lamina.

Neural spines are reduced and not expanded distally, contrary to the condition of *Argentinosaurus*, and are narrower and more compressed anteroposteriorly than in *Mendozasaurus*. Prezygapophyses are placed almost horizontally, different from the inclined condition observed in *Mendozasaurus* and *Argentinosaurus*. In the posterior elements the spinoprezygapophyseal lamina is transformed in a spinodiapophyseal lamina (Fig.13). The supradiapophyseal cavity is reduced, placed on the neural spine and turns into a slit-like depression in dorsal 2. The well developed spinopostzygapophyseal and diapopostzygapophyseal laminae are preserved in all elements of the series. Dorsals 3 and 4 have the ventral surface of the centrum convex. From dorsal 5 to the end, the centrum has a ventral ridge, differing from the flattened condition observed in *Argentinosaurus*.

Sacrum

The sacrum is formed by six elements with a total length of 96cm (Fig.15). The width of the sixth sacral vertebra with ribs is 117cm, but including the ilium it reaches 136cm. The first sacral width, including ribs and the preacetabular laminae, is 255cm. The length of the first sacral rib from tip to tip is 200cm. They extend laterally over the upper border of the preacetabular laminae of the ilia. The centrum of the first sacral is 45cm wide and 38cm high. The sixth sacral vertebra is the longest element with the anterior surface 35cm wide and 27cm high. The first and second sacral vertebrae have the ventral surface flat, whereas in the remaining elements it is convex. *Futalognkosaurus* possesses the 2nd and 3rd sacral ribs fused, a featured not observed in any other Titanosauria (Fig.15). The last sacral has a convex posterior surface different from *Aeolosaurus rionegrinus* (Powell, 1986), *Pellegrinisaurus powelli* (Salgado, 1996), *Alamosaurus sanjuanensis* (Gilmore, 1946), *Neuquensaurus australis* (Huene, 1929; Powell, 1986), Titanosauridae indet. MCT 1536-R (Campos & Kellner, 1999), and *Opisthocoelicaudia skarzynskii* (Borsuk-Bialynicka, 1977).

Caudal vertebra

Only one anterior caudal element, probably the 1st, was found so far (Figs. 16-17). It is strongly procoelous, with rounded posterior (40x40cm) and anterior (42x42cm) surfaces. The neural arch is inclined posteriorly and the transverse processes are wide, elongated dorsoventrally and directed laterally. The neural spine is distally expanded, a feature unique to *Futalognkosaurus* (Fig.16).

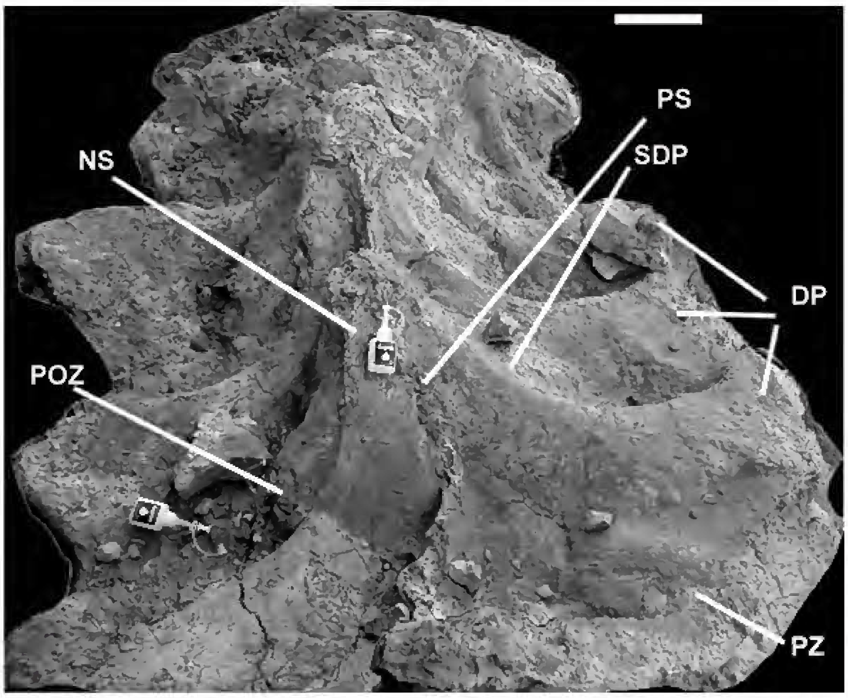

Fig.14- *Futalognkosaurus dukei*; anterior dorsals in anterior view. Scale bar =100mm. (DP) diapophysis, (NS) neural spines, (POZ) postzygapophysis, (PS) prespinal lamina, (PZ) prezygapophysis, (SDP) spinodiapophyseal lamina.

The prespinal lamina is strongly developed and joins the postspinal lamina by another lamina that crosses the distal end of the neural spine, here called supraspinal lamina (Figs.16-17). The prespinal lamina bifurcates on its base, forming two small infraprespinal laminae, another feature unique to this titanosaur (Fig.17). On anterior view, there are two deep "supraspinal" cavities on the neural spine, bordered by the prespinal and two lateral laminae (Fig.17). The lateral laminae start on the top of the prespinal lamina as spinoprezygapophyseal laminae and curve downwards to reach the base of the prespinal lamina at the level of the prezygapophysis. Those supraspinal cavities are considered an autopomorphic feature of *Futalognkosaurus dukei*.

PELVIS

The right pubis is a robust and laminar bone (Fig.18). The iliac articulation is the widest and the iliac process of the pubis is poorly defined. The external surface presents a longitudinal ridge as in *Aeolosaurus* and *Opisthocoelicaudia*, producing two concave surfaces, with the anterior one wider than the posterior. The distal end of the pubis is stout, slightly expanded in lateral view and has a suboval shape in posteroventral view. The distal end is 43,5cm wide. The oval pubic foramen is closed and placed near the puboischial contact. The shaft of the pubis is very long, reaching a total length of 137cm. The contact surface of the pubis with its counterpart is proximally thin and wide distally, where it shows a quadrangular shape.

The ischia are laminar and thin, having a well defined iliac process (Fig.19). The iliac articulation is long, well defined proximally and thinner on the distal end. The shaft is twisted medially. The contact with the pubis is long and curved. The contact surface with the other ischium is restricted only to the distal end; by contrast, in *Rinconsaurus* and *Opisthocoelicaudia* there is a complete contact between both ischia.

Both ilia are preserved, having a maximum height of 96cm. The preacetabular laminae are directed outward as in other Titanosauria. The separation of the iliac peduncles is 137cm. No particular feature that distinguishes those elements from other titanosaurs was observed.

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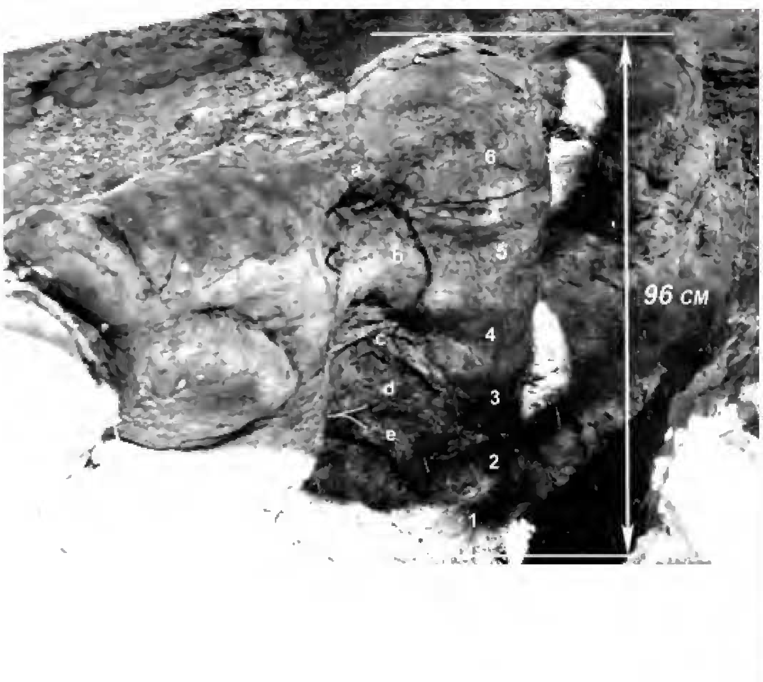

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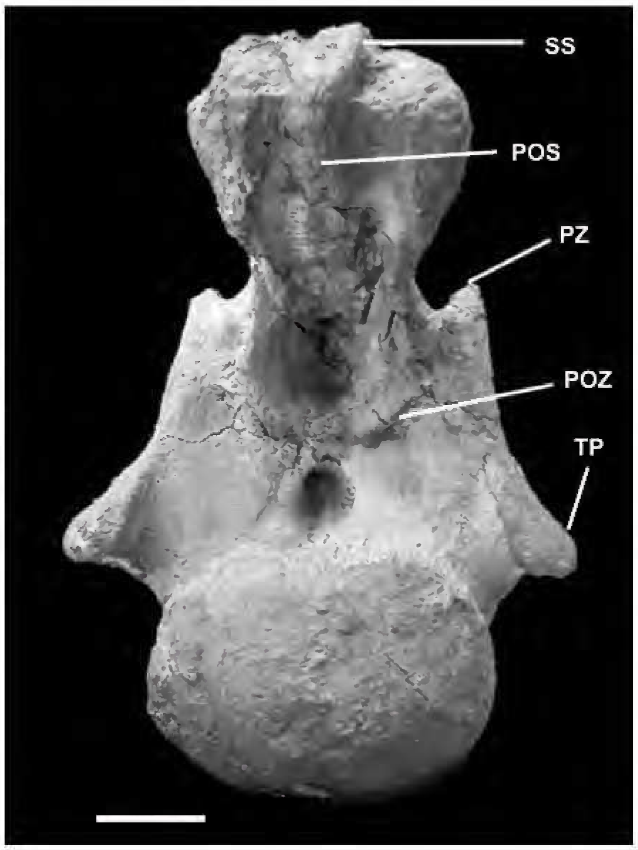

Futalognkosaurus dukei: fig.15- sacrum in a postero-ventral lateral view (field picture); fig.16- 1st caudal in posterior view, scale bar =100mm. (POS) postspinal lamina, (POZ) postzygapophysis, (PZ) prezygapophysis, (SS) supraspinal lamina, (TP) transverse process.

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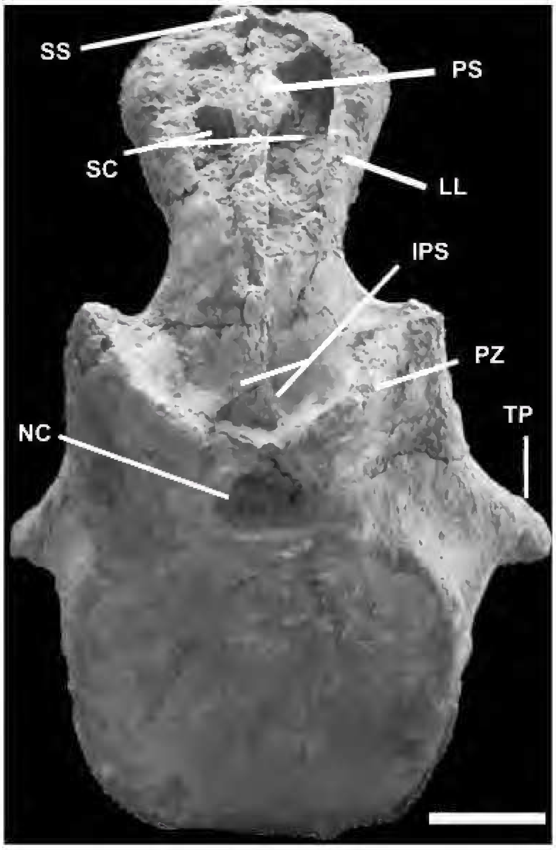

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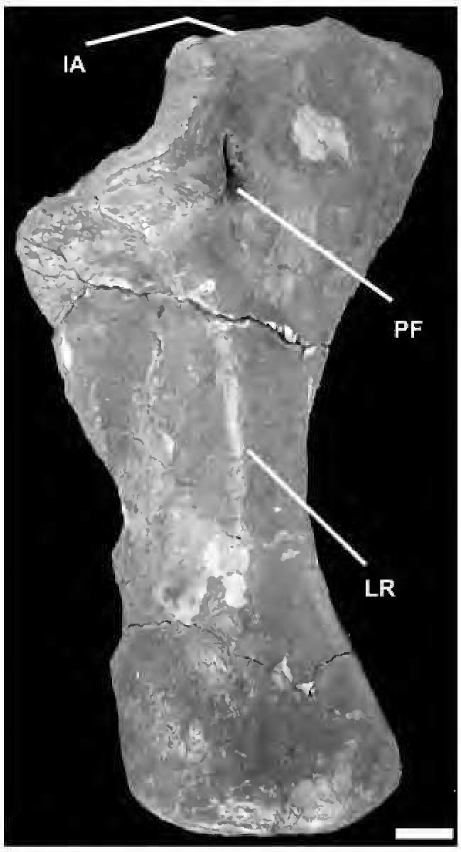

Futalognkosaurus dukei: fig.17- 1st caudal in anterior view; fig.18- right pubis in lateral view. Scale bar =100mm. (IA) iliac articulation, (IPS) infraprespinal laminae, (LL) lateral laminae, (LR) longitudinal ridge, (NC) neural canal, (PF) pubic foramen, (PS) prespinal lamina, (PZ) prezygapophysis, (SC) supraspinal cavity, (SS) supraspinal lamina, (TP) transverse process.

DISCUSSION AND CONCLUSIONS

Titanosauria is one of the sauropod groups more extensively widespread, particularly in Gondwana. Recent cladistic analyses have improved the knowledge about the relationships of several titanosaurid taxa (SALGADO *et al.*, 1997a,b; WILSON & SERENO, 1998; UPCHURCH, 1998; WILSON & UPCHURCH, 2003; CALVO *et al.*, 2007; CALVO *et al.*, this volume).

CALVO *et al.* (this volume) made a detailed analysis that supported the higher level grouping of Titanosauria (BONAPARTE & CORIA, 1993); moreover, the inclusion of *Futalognkosaurus* (CALVO *et al.*, 2007) in that analysis confirmed it as a Titanosauridae (*sensu* SALGADO *et al.*, 1997a). *Mendozasaurus* and *Futalognkosaurus* form the clade Lognkosauria CALVO *et al.* (2007) (Fig.20), which is based on five synapomorphies: presence of a laterally expanded posterior cervical neural spines, wider than the centra, posterior cervical vertebrae with a height 1.5 the length of the centra, deep and extended supradiapophyseal cavity in posterior cervical vertebrae, posterior cervical centra proportions: ratio anteroposterior length / height of posterior face less than 1.5, and transversely elongated neural spines in dorsal view on most anterior caudal vertebrae. *Futalognkosaurus dukei* differs from other titanosaurids in the following unique combination of traits: quadrangular and laminar posteriorly directed neural apophysis in the axis, high and triangular neural spine of the atlas, concave posterior border on posterior cervical neural spine, horizontal aliform diapophysis on anterior dorsals, supradiapophyseal depression on posterior cervicals, horizontal pre- and postzygapophysis on anterior dorsals, two deep cavities aside the prespinal bordered by the spinoprezygapophyseal laminae, fusion of sacral ribs 2nd and 3rd.

Among the giant titanosaurid sauropods are *Argentinosaurus huinculensis* (BONAPARTE & CORIA, 1993), *Puertasaurus reuili* (NOVAS *et al.,* 2005), and

Futalognkosaurus dukei (Calvo *et al.*, 2007). *Argentinosaurus* is represented by only 10% of its skeleton and *Puertasaurus* by just 3% of the total elements. By contrast, *Futalognkosaurus* is represented by almost 70% of the total skeleton being the most complete giant sauropod ever found. *Puertasaurus* is represented by very poor material, but shares several characters with other members of the Lognkosauria (Calvo *et al.*, 2007), such as the absence of pleurocoels in cervical vertebra, transversely expanded neural spine in posterior cervicals, and anterior dorsal neural spines inclined less than 20 degree from vertical. Therefore, *Puertasaurus* can be considered as a basal member of Titanosauridae closely related to Lognkosauria.

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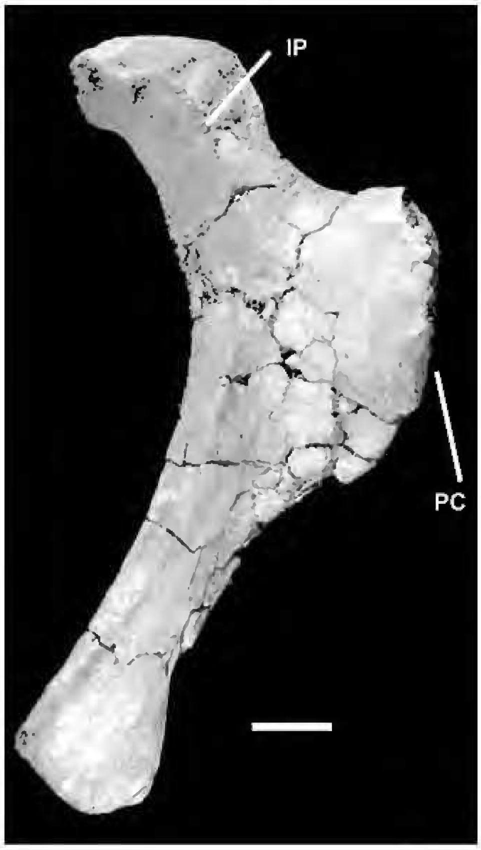

Fig.19- *Futalognkosaurus dukei*; right ischium in lateral view. Scale bar =100mm. (IP) iliac process, (PC) pubis contact.

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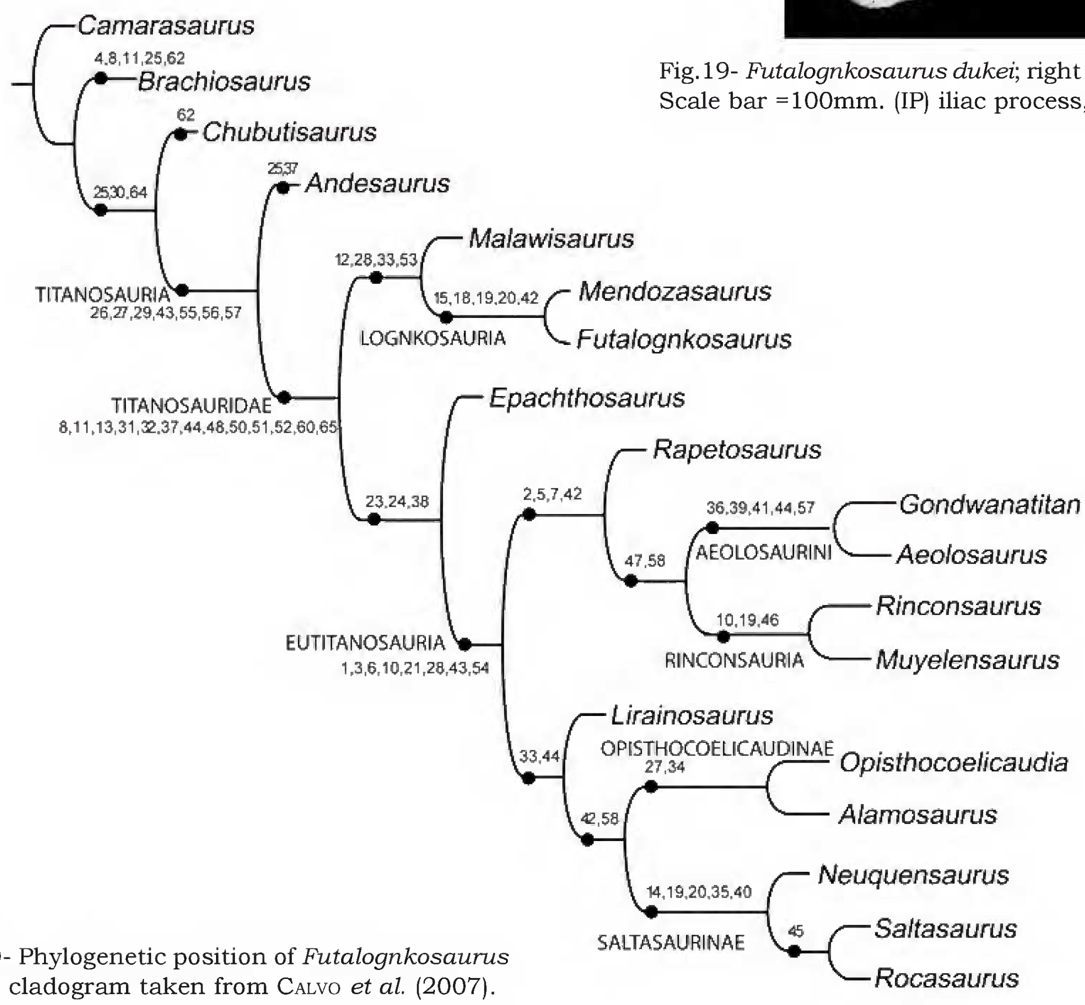

Fig.20- Phylogenetic position of *Futalognkosaurus dukei*; cladogram taken from Calvo *et al.* (2007).

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